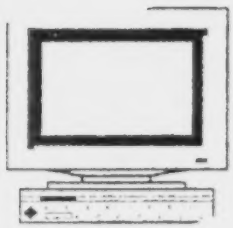
Safety of Mine Hoists Controlled by Programmable Systems



ÉTUDES ET RECHERCHES

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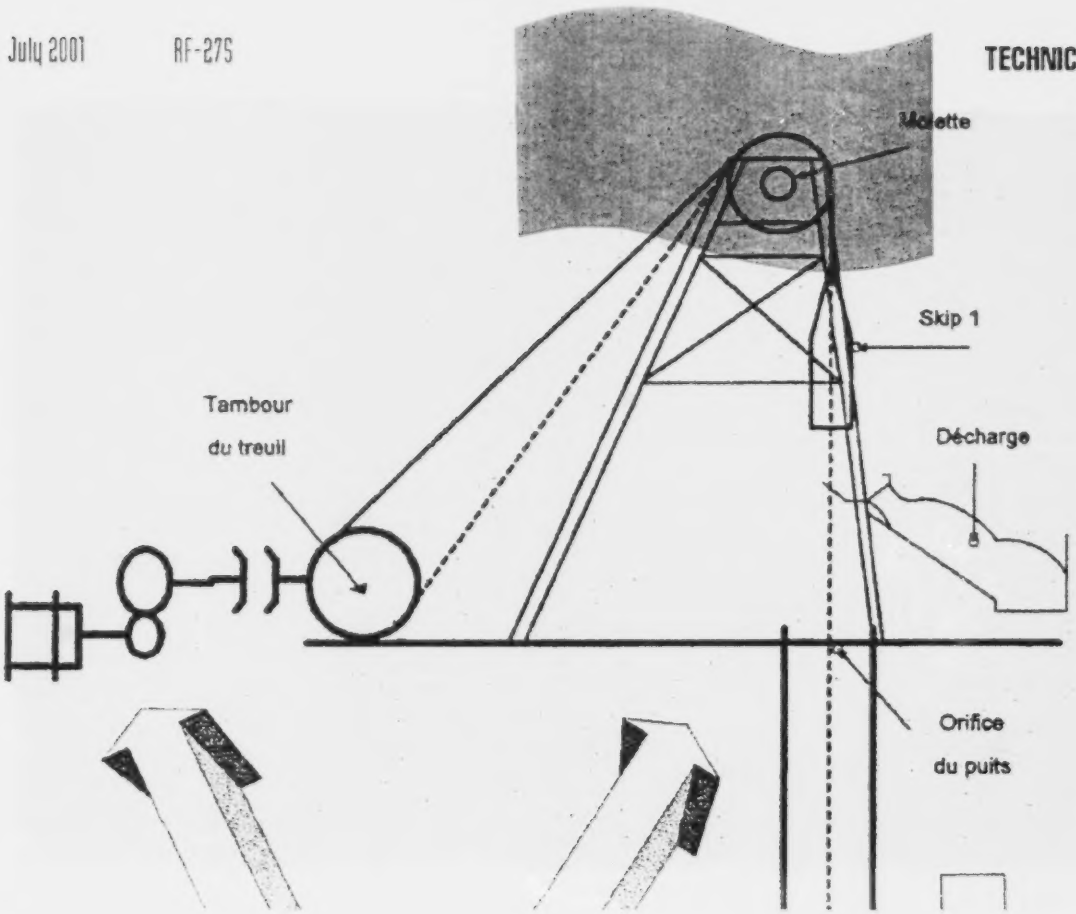
July 2001 RF-275

TECHNICAL GUIDE



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Safety of Mine Hoists Controlled by Programmable Systems

ÉTUDES ET RECHERCHES

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1 INTRODUCTION

1.1 Definitions

The guide on mine hoists [4], based on the regulation dealing with safety in Québec mines [5] provides information for those interested in the operation of mine hoists. It presents the various safety mechanisms and provides the necessary information for ensuring that the machines operate properly. At the time that the guide [4] and the regulation were prepared, programmable control technologies were not yet readily available. With the rapid evolution in new technologies and the desire to achieve cost-effective investments, **programmable control systems (PES)** have been progressively implemented in all industries. The mining sector has not escaped this trend and several Québec mines have equipped their hoists with programmable control systems. However, the introduction of these new technologies, required for improved productivity in Québec mines, must not increase the level of risk in Québec mines.

It should be remembered that in the terminology of **programmable control systems,** whose French or English acronym is **PES** [6], there are several computer-based **programmable electronic technologies (PE)** that include hardware, software, as well as data input and/or output units. This terminology covers microelectronic devices based on one or more central processing units (CPU) associated with memory, etc. For example, all of the following devices are programmable electronic devices:

- microprocessors;
- microcontrollers;
- application-specific integrated circuits (*ASIC*);
- programmable controllers (*PC*) or programmable logic controllers (*PLC* or IPC);
- other devices based on computer technology (for example smart sensors, transmitters, actuators, speed regulators, cycloconverters, etc.).

Programmable electronic systems (PES in English and in French) are themselves defined [6] as **control, protection or monitoring systems** based on one or more **programmable electronic** devices. This term covers all the system's components, such as the power supply, sensors or other input devices, as well the actuators or other output devices, and including the data highways or other routes of communication.

1.2 Reliability of PES

From the standpoint of safety and as mentioned in INRS Note Documentaire no. 117 [7], programmable controllers have three main reliability characteristics that are different from those of the previously-used controllers based on electromechanical technology: (free translation)

- *"The programmable controller's failure modes are not well known, and in addition, its behavior on internal failure cannot be anticipated";*

4 Fortin, G., Demers, R., Les machines d'extraction, Guide, Commission de la Santé et de la Sécurité du Travail du Québec, 1993.

5 Regulation respecting occupational health and safety in mines, S-2. 1, r. 19. 1, Gouvernement du Québec, 1998.

6 Sécurité fonctionnelle: systèmes relatifs à la sécurité, Partie 4: Définitions et Abréviations, Commission Électrotechnique Internationale, Comité technique no. 65: Mesure et Contrôle du Procédé industriel, IEC 61508-4, 53 pages, 1998.

7 Vautrin, J.-P., DEI SVALDI, D., Les automates programmables: Nouvelles technologies, nouveaux risques, principes de sécurité à appliquer, Institut National de Recherche en Sécurité, Cahiers de Notes documentaires, ND 117, 1984

- *"Conducted or radiated electrical interference can produce an extremely disturbing effect"* (particularly from the radio communication systems used in mines);
- *"The possibility of rapid modifications of programs" provides a flexibility that may introduce additional risks."*

INRS note documentaire no. 117 [7] then recommends that the rules below be followed: (free translation)

"With the current state of knowledge:
1) Direct safety functions must not be taken into consideration solely by the programmable controller. Even if the safety data (emergency stop, protectors) can be input data for the controller, the data must necessarily act directly on the actuators. In other words, direct safety must not be basically dependent on the expected proper operation of the controller.
2) If controllers are to be used regardless, to ensure direct safety, specific solutions must be implemented (dynamism, doubling of controllers). The safety level achieved must also be as high as for positive safety hard-wired logic. In particular, a failure must not result in a hazardous situation. In the case where a doubling of controllers is chosen, common failure modes affecting the two channels must be scrupulously eliminated.
3) Indirect safety functions (self-checking function, synchronism, controls) can be carried out equally by cabled logic or programmed logic, with both employing commonly accepted practices."

This restriction regarding the safety applications of programmable controllers also appears in the note to paragraph 11. 3. 4 of IEC 60204-1 standard [8]: "*In situations where a significant hazard can occur due to maloperation of the control system, it is currently difficult to determine with any degree of certainty that reliance on correct operation of a single channel of programmable electronic equipment can be assured. Until such a time that this situation can be resolved, it is inadvisable to rely solely on the correct operation of such a single-channel device.*"

1.3 Risk analysis

The process that led to the current recommendations on control and monitoring systems that use programmable technologies is identical to the process that was adopted to establish the regulation [5] as well as the guide [4] on the safety of mine hoists. The latter process was based on an informal risk analysis that was developed from the experience of users, manufacturers and CSST inspectors, and that led to a certain number of recognized solutions being prescribed. In preparing this technical data sheet, this non-formalized analysis process was extended to mine hoist control and monitoring systems that use programmable technologies, while referring to experiences in the mining industry when available, and by making use of experience from other applications of programmable control technologies in other types of industries, often put into concrete form as specific standards.

Although the need for a more global and more formalized analysis process for the risks associated with mine hoists was felt, general standards now exist for machine hazard analysis [9], control system safety [10], and machine safety in general [11, 12], which should be consulted.

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8 Equipement électrique des machines industrielles - Partie 1: Régles générales Commission Électrotechnique Internationale. CEI/IEC60204-1, 2000.

9 Sécurité des machines. Principes pour l'appréciation du risque. Norme Européenne EN 1050, Novembre 1996. (ISO 14121)

10 Sécurité fonctionnelle: systèmes relatifs à la sécurité, Parties 1 à 7, Commission Électrotechnique Internationale, Comité technique no. 65: Mesure et Contrôle du Procédé industriel, IEC 61508-1/7, 1998.

11 Sécurité des machines. Notions fondamentales, principes généraux de conception - Partie 1: Terminologie de base, méthodologie. Projet de norme

1.4 Use of the technical data sheet

This technical data sheet is intended for users and installers of PES-controlled mine hoists. It will in no way modify the basic safety requirements of the regulation and the guide. It provides additional information on the objectives to be achieved in terms of the safety of PES-controlled mine hoist systems. This document is provided for information purposes only and does not preclude the designer or user from the obligation of complying with all legal or regulatory requirements related to their operations. The safety data sheet's recommendations cover in particular the general structure of the control and monitoring systems of PES-controlled mine hoists, their specific components and the required periodic tests and checks.

Application of the technical data sheet should ensure that the current safety level of mine hoists is maintained when these machines are controlled by PES.

This technical data sheet is published on a trial basis and will most likely be revised or incorporated with modifications into the guide on mine hoists [4], depending on the comments received and the results of the trial.

internationale, ISO/CD 12100-1 : 199X, (voir aussi EN 292-1), Février 1998.

12 Sécurité des machines, Notions fondamentales, principes généraux de conception - Partie 2: Principes et spécifications techniques, Projet de norme internationale, ISO/CD 12100-2 : 199X,

2 GENERAL STRUCTURE OF THE CONTROL AND MONITORING SYSTEMS FOR PES-CONTROLLED HOISTS

2.1 General principles of the structure of the control and monitoring system

This document's recommendations in no way modify the general structure of the control and monitoring systems for mine hoists installed in Québec. Regardless of the technology used to produce these systems, the general principle is still a total separation between the basic control functions and the functions of monitoring the proper operation of the installation. The prescribed periodic tests complete this principle by enabling the operator to ensure that mechanical, electrical and electronic operating safety is maintained.

The general structure of the control and monitoring systems for PES-controlled mine hoists is shown in figure 1 of the appendix. It contains the following main components:

2.2 Control PES

The control part acts on the power commutation equipment, thus allowing the speed of the hoist to be varied when the motors are powered by alternating current. For hoist motors powered by direct current, the control equipment regulates the speed.

When a PES is used, the maximum permitted speed is automatically limited by the encoders in relation to the distance remaining between the conveyance and the limits of travel.

Furthermore, the motor controls act on the service brake release in normal operation and trigger the opening of the safety circuit following the initiation of one of the following failures (incomplete list):

- motor and electrical network protection;
- various types of temperature protection;
- brake protection;
- limits of travel protection;
- wire rope protection;
- operation protection and indicator;
- shaft sinking protection.

The safety devices for PES-controlled hoists can produce four types of action:

Type 1: immediate stopping of the machine by opening the safety circuit (emergency braking).

Type 2: automatic stopping of the machine by the driving force (dynamic braking) by opening the safety circuit (the problem that caused the initiation must be corrected before the hoist can be reset). This stopping can occur anywhere along the path of the conveyance.

Type 3: after normal stopping of the machine, opening of the safety circuit (the problem that caused the initiation must be corrected before the hoist can be reset).

Type 4: alarm to the operator indicating the potential problem detected, without initiating stopping.

2.3 Safety circuit

The components of the safety circuit should use a proven technology such as electromechanical relays, push buttons and direct wiring, such that any opening of the electrical circuit (electric wire, failure of a coil, etc.) results in the stopping of the machine.

The opening of the safety circuit leads to the suppression of the power supply to the hoist motor and triggers emergency braking.

When the protection initiation signals originate from the PES control or monitoring part, these signals should be generated through at least three outputs, with two supplying two independent relays, and the third being used to activate the external timer (see 3. 1. 3). These three relays are then an integral part of the safety circuit, and the hoist cannot be started if the active contacts are not in the "off"position (contact movement self-checking).

The following safety signals should be directly wired to the safety circuit with sturdy contacts:

- The overwind switch and its backout switches;
- The overload relay for the D.C. loop;
- The emergency stop switches at the manual controls;
- Failure of the monitor (2 relays and one external timer);
- Failure of the control (2 relays and one external timer).

2.4 Emergency brakes

This device is activated electrically by the safety circuit. Should the safety circuit open, the emergency brakes are then applied. The emergency brakes are applied by their own devices on a priority basis. The safety-circuit contacts that supply power to the solenoid valve coils must have sufficient capacity to supply the current required by the emergency brakes.

2.5 Power stages of the motor

Power can be supplied in several different ways to a hoist motor mainly to vary its speed. Power semi-conductors are being increasingly used in conjunction with microprocessors dedicated to this specialized application.

Improper operation of the power stages should result in the immediate opening of the safety circuit as well as the opening of a primary circuit breaker and/or a circuit breaker on the D.C. loop (loop breaker). In all cases, energy should only be transmitted to the motor when the safety circuit is closed.

The opening of the safety circuit for a problem unrelated to the power stage may, for a period of less than one second, maintain energy to the motor in order to avoid acceleration of the conveyance.

2.6 Monitoring PES

The speed monitoring system, sometimes called the speed controller, can be mechanical, electronic, or a combination of the two. Approximately 17 hoists were equipped with **monitoring PES** between 1993 and 1999 in Québec.

The role of the monitoring PES is to immobilize the hoist by using a type 1 stop (Type 1: immediate

stopping of the machine by opening the safety circuit).

The protection normally performed by the monitoring PES mainly includes:

- overspeed in the entire shaft;
- limits of travel;
- auxiliary overwind;
- and various other types of protection.

3 SPECIFIC ASPECTS OF PES-CONTROLLED CONTROL AND MONITORING SYSTEMS

3.1 General principles to be applied

Note: The general principles presented below have been taken either from already established and validated practices for PES used with mine hoists, or from mandatory recommendations for PES in IEC 61508-2 [13] or from general recommendations on IPC and safety [14].

Any PES or component of a PES that controls or monitors a mine hoist must comply with the following general principles.

3.1.1 Channel separation

The first principle to apply is the complete separation of the hoist's main control system and the monitoring system, including the measuring devices (sensors and transmitters) and up to the power actuators (brakes and power equipment), but not including the actuators. One encoder per drum and one checking encoder must be supplied and used.

3.1.2 Protection against environmental influences

3.1.2.1 Power supply

The control and/or monitoring system must be protected from any variation or drop in voltage as well as from any power surges. For example, any increase or drop in voltage in the control or monitoring circuits must be detected early enough so that the internal states can be stored in nonvolatile memory if necessary and all the outputs can be brought to safe positions, or a backup power unit connected [A. 8 of 13].

3.1.2.2 Separation between power lines and data lines

The power supply lines must be physically separate in order to reduce the effect of power voltage pulses on the control and data lines [A. 11. 1 of 13].

3.1.2.3 Increased immunity to interference

Specific techniques such as shielding and filtering must be employed to increase the unit's immunity to interference from the control or monitoring system, and to electromagnetic interference that may

13 Sécurité fonctionnelle: systèmes relatifs à la sécurité, Partie 7: Présentation de techniques et de mesures, Commission Électrotechnique Internationale, Comité technique no. 65: Mesure et Contrôle du Procédé industriel, IEC 61508-7, 65A/256/CDV, 3-4-98.

14 PAQUES, J.-J. Règles sommaires de sécurité pour l'utilisation des automates programmables industriels (API). Étude/Bilan de connaissances B-028, 19 p. IRSST, Montréal. (Janvier 1991).

be induced or conducted in the power cables or from signals or that may result from electrostatic discharges [A. 11. 3 of 13].

3.1.2.4 Protection against the environment

It is always advisable to ensure that the control or monitoring system's installation conditions are acceptable and correspond to the manufacturers' recommendations, for example, for temperature, dust, humidity, corrosion or emissions of electromagnetic radiation [6.2.8 of 14].

3.1.3 External watchdog function

To ensure that the program operates normally, a function must be inserted in the program that activates an output from each PES in a time interval of less than one second. This pulsed output is connected to a timer outside the PES.

The disappearance of pulses results in the opening of the safety circuit. In this way, we make sure the program is not frozen, either due to a change caused by radiated electromagnetic interference or due to undetected sequence looping during the tests.

3.1.4 Guided contact relays

Electromechanical guided contact relays, which are used in safety circuits, can perform cyclical self-checking sequences, as for example at the start of each safety circuit reset.

3.1.5 Protection against changes

3.1.5.1 Protection against physical changes

Changes or manipulations whose consequences could affect the safety of the control or monitoring system must be automatically detected, for example by validation of a sensor signal, by technical detection (use of a key switch, systematic tests at start-up, etc.). If a change is detected, an emergency action is performed [B. 4. 8 of 13].

3.1.5.2 Parameterization and programming

The control PES must have the following programming characteristics:

- Basic programming of the PES as well as fixed parameterization of the system will not be accessible by the mine hoist operator;
- Parameterization and calibration will be reserved for clearly identified persons and carried out according to procedures that ensure the safety of the modifications made;
- Any change of this type or for maintenance can only be done in protected mode with a personalized access code or using a procedure with an equivalent level of security;
- After an intervention with the use of a code, protected access must resume automatically after a certain period of time so that unprotected mode does not continue permanently;
- If changes in program or operating parameter are planned to be made from a distance, safety measures must be implemented to ensure that these modifications from a distance have a safety level equivalent to that obtained if the changes were made within view of the machine.

3.1.6 Functional tests

After installation, the control or monitoring system must undergo complete functional testing to verify in what way the specifications have been met. For this, data that properly characterizes normal operation will be introduced. The outputs will then be observed and their responses compared to those indicated by the specifications. Deviations from specifications and indications of incomplete

specifications will be documented [B. 5. 1 of 13].

3.1.7 Reliability of components

Any failure of a system component could result in the hoist stopping; consequently, for prevention purposes, the reliability of the components used has a direct impact on the availability of the hoist. It is therefore very important that the components be chosen with care and that they have maximum reliability.

In addition, the control and monitoring systems must be easily capable of withstanding the normal and abnormal conditions that can be expected in this type of installation (removal of a card, partial or total loss of power, environmental conditions, etc.). In particular, the partial or total loss of electrical power must not lead to loss or modification of a program, parameter or any other data required for the safe operation or maintenance of the hoist and its control system.

3.1.8 Memory

The memory used in control and monitoring PES must be permanent or at least provide sufficient data retention after a loss of electrical current to stop movement and bring the hoist to a stable and safe state for workers.

3.1.9 Communication networks

A monitoring PES must not be connected to any communication network other than that required for its own operation.

In particular, any change in program or operating parameter must preferably be made near the machine, or if necessary, through the hoist-dedicated network.

3.1.10 Protection against anomalies during operation and maintenance

To reduce the risks associated with the operation or maintenance of the control or monitoring system, instructions containing essential information on system use or maintenance must be provided. In some cases, these instructions will also cover system installation. All the instructions must be easy to understand. Diagrams and figures must be used to describe complex procedures or systems.

To reduce operating complexity, the control or monitoring system designer must make every effort to ensure that [15]:

- The need for human intervention is reduced to a strict minimum;
- The required interventions are as simple as possible;
- The potential for damage due to operator error is reduced to a minimum;
- Control and signaling devices are designed according to ergonomic principles;
- Interfaces with the operator are simple, well identified and can be used intuitively;
- The operator does not have too much to do, even in extreme situations;
- Training in intervention procedures is based on the users' level of knowledge.

In the same way, in order to facilitate maintenance and repairs, which are often done under difficult circumstances and under pressure due to deadlines, the control or monitoring system designer must ensure that:

15 Contrôleurs programmables - Partie 4 : Directives pour l'utilisateur, Comité Électrotechnique International, CEI 1131-4, 1995.

- Maintenance procedures on control or monitoring systems are reduced to a minimum, if it is impossible to avoid them completely;
- Sufficient significant and easy-to-handle diagnostic tools are included for unavoidable repairs;
- If diagnostic tools must be developed or obtained, they should be supplied in time.

3.1.11 Monitoring profile

The monitoring profile must be introduced manually by taking into account the deceleration in an emergency situation under the most unfavorable conditions (for example at full load and full speed).

3.1.12 Checkpoint

One checkpoint per drum should be physically installed in the shaft, inside the upper retarding zone, to confirm on each trip the speed and position of the conveyance at this point. Proper operation of the checkpoint must be checked during each cycle.

3.1.13 Calibration of the depth indicator

The encoders installed on the hoist and connected to the PES (control or monitoring) are used to determine the position and speed of the conveyance in the shaft. The number of pulses per drum revolution must be sufficient to obtain a precision of at least 0.75 inch (1.9 cm) in the shaft on the first layer of wire rope. The pulses accumulated in relation to a known reference point allow the PES to calculate the position of the conveyance. Calibration in relation to this reference must be done manually and must be redone when the difference between the calculated position and the actual position is greater than the extension in the wire rope at the loading level (difference between the conveyance loaded with ore and empty).

- For friction hoists, the pulses always represent the same distance in the shaft. Calibration can be done from a single fixed point in the shaft other than the checkpoint defined in 3.1.12.
- For drum hoists, the pulses represent a different value depending on the number of layers of wire rope wound on the drum. Calibration should then be done manually with a known position and a position on another layer of wire rope.

3.2 Optional requirements

To improve the reliability and maintenance of a PES that controls or monitors a hoist, the following measures are strongly recommended:

3.2.1 Recording of events

By regularly updating work and incident files on computer, which is one means of controlling normal and abnormal operations, any operation can be traced, and later, the sources of problems that could affect the reliability or safety of the PES that controls or monitors a hoist can be diagnosed. Operating or incident data can then be easily printed and archived and used when incidents occur. For example, a monthly systematic analysis of incidents could help prevent major incidents.

3.2.2 Specific monitoring

PES can be the subject of specific monitoring, which is often proposed by manufacturers. Some examples are: monitoring of memory failures, internal watchdog, programmed watchdog, etc.

3.2.3 Bypassing of certain protection functions by the hoist operator

Situations may be encountered in which a type of protection must be bypassed so that the hoist can be brought to a normal position. These situations may include:

- testing of the overwind;

- a door causing an obstruction in the shaft;
- protection of the position of the skip locks;
- lower limit of travel when a permanent stop is used;
- other types of protection.

In all these situations, bypassing must be carried out within a predefined context. The context in which the protection must be bypassed must introduce restrictions into normal operation, or else result in the use of other auxiliary safety devices.

3.2.4 Risk analysis

If there is any doubt as to the preventive measures to be used and if this technical data sheet does not answer all the questions, it is strongly recommended that a complete risk analysis be carried out on the hoist, including the control and monitoring PES, based on the most recent standards [7, 10, 11 and 12].

4 PERIODIC TESTS AND CHECKS

The list of the identified types of protection is intended to be as comprehensive as possible. Each mine is responsible for completing its own inspection records on the hoisting equipment in order to plan for the inspection of all protection specific to each hoist installation.

A proven test procedure will be written for each type of protection and used for the inspections.

Reminder: *Safety devices for PES-controlled hoists can produce four types of actions, which are indicated in the third or fourth column of the following tables:*

Type 1: immediate stopping of the machine by opening the safety circuit (emergency braking).

Type 2: automatic stopping of the machine by the driving force (dynamic braking) by opening the safety circuit (the problem that caused the initiation must be corrected before the hoist can be reset). This stopping can occur anywhere along the path of the conveyance.

Type 3: after normal stopping of the machine, opening of the safety circuit (the problem that caused the initiation must be corrected before the hoist can be reset).

Type 4: alarm to the operator indicating the potential problem detected, without initiating stopping.

4.1 Motor and electrical network protection

Type of protection	Article [S-2.1, r. 19.1]	Proposed inspection frequency	Control PES	Monitoring PES
Loss of one phase of the main power supply		Annually	Type 1 action	
Instantaneous motor overloads (short circuit)	232 7), 233 7)	Weekly	Type 1 action	
Delayed motor overloads	232 7), 233 6)	Weekly	Type 1 action	
Drop in voltage in electrical system	232 7), 233 5)	Weekly	Type 1 action	
Sudden loss of field (direct current shunt motor)		Annually	Type 1 action	
Ground continuity detector for the different power supplies to the hoist		Annually	Type 3 action	
Loss of hoist motor torque		Annually	Type 1 action	
Instantaneous and abnormal overload opening of the direct current loop		Annually	Directly on the safety circuit	

4.2 Temperature protection

Type of protection	Article [S-2.1, r. 19.1]	Proposed inspection frequency	Control PES	Monitoring PES
Temperature of the alternating current motor grid resistances		Annually	Type 4 action	
Cooling air flow for hoist motor(s)		Annually	Type 4 action	
Temperature of motor coils		Annually	Type 4 action	
Temperature of the disk brake(s) of the drum		Annually	Type 4 action	
Temperature of brake hydraulic circuit		Annually	Type 4 action	

4.3 Brake protection

Type of protection	Article [S-2.1, r. 19.1]	Proposed inspection frequency	Control PES	Monitoring PES
Normal wear on brake pads	232 8), 233 8)	Weekly	Type 3 action	
Pressure available for brake release		Annually	Type 2 action	
Brake not applied (protection on calipers)		Annually	Type 1 action	
Brake not released		Annually	Type 1 action	
Brake applied before disengaging a drum	251	Weekly	Type 1 action	
Interlocking of drum brake application after disengaging (mechanical and electrical)	251	Weekly	Type 1 action	
Application of service brakes before the operator's signal (shaft signal system)		Monthly	Type 3 action	
Discrepancy between the desired braking method (slow or fast) and the one applied.		New requirement; see note 16	Type 3 action	

16 The testing frequency may not be required when the PES performs a self-check routine of the protection in question as for example when the encoders are continually performing self checks.

4.4 Limits of travel protection

Type of protection	Article [S-2.1, r. 19.1]	Proposed inspection frequency	Control PES	Monitoring PES
Overwind limit switch (track limit)	232 2), 233 2)	Weekly	Directly on the safety circuit	
Upper limit of travel	232 3), 233 2)	Weekly		X
Lower limit of travel	232 3), 233 2)	Weekly		X
Protection of persons (auxiliary overwind prevention)	235	Weekly		X
Safety doors (surface) or other obstacles in the shaft	388	Weekly	Type 2 action	
Checking of hoist deceleration at the limits of travel in the shaft. (-25% from the start of retarding zone)	237 3)	Weekly		X
Hoist synchronization		Weekly	Type 1 action	

4.5 Wire rope protection

Type of protection	Article [S-2.1, r. 19.1]	Proposed inspection frequency	Control PES	Monitoring PES
Slack rope		Weekly	Type 1 action	
Device on the conveyance for checking the application of safety catches (gripgear)		Weekly	Type 1 to 4 action	
Continuous measuring device for the rope section		Monthly (depending on manufacturer)	Type 3 action	
Slipping of wire rope on pulley	237 1)	Weekly	Type 1 action	
Loop of a tail rope	237 2)	Weekly	Type 1 action	

4.6 Operation protection and signaling

Type of protection	Article [S-2.1, r. 19.1]	Proposed inspection frequency	Control PES	Monitoring PES
Overspeed outside the retarding zones (men)	235, 232 4), 241 1)a	Weekly		X
Overspeed outside the retarding zones (ore)	232, 241 1)a	Weekly		X
Overspeed at the limits of travel	241 1)b	Weekly		X
There is too great a difference in the hoist's position and speed between the control PES and the monitoring PES		Continuous check	Type 2 action	
Sound warning when the speed approaches overspeed	241 2)	Weekly	Type 4 action	
Wrong direction of the conveyance in relation to the command given		Annually	Type 2 action	
Wrong direction of the ore load (load down)		Annually	Type 2 action	
Emergency power cut-off switch at the operator's controls (console)	232 1)	Weekly	Directly on the safety circuit	
Emergency power cut-off switch installed underground (loading level or other)		Monthly	Type 1 action	
Conveyance position indicator	243	Weekly		
Speed indicator	232 9)	Weekly		
Sound signal when the conveyance enters a retarding zone	244	Weekly		
Protection applicable to a skip equipped with a tipper tub	330	Weekly	Type 2 action	
Current indicator for the hoist motor(s).	232 6)	Weekly		
Monitoring of the internal operation of the PES		New requirement; see note 16	Type 1 action	X

Type of protection	Article [S-2.1, r. 19.1]	Proposed inspection frequency	Control PES	Monitoring PES
Key resulting in the stopping of the hoist to change the program of a hoist PES.		New requirement; see note 16	Type 1 action	X

4.7 Safety circuit reset or interlock protection

Type of protection	Article [S-2.1, r. 19.1]	Proposed inspection frequency	Control PES	Monitoring PES
Joystick in neutral position to reset the hoist		Weekly	Prevents reset after emergency stop	
Brake completely applied to reset the hoist	249	Weekly	Prevents reset after emergency stop	
Monitoring of the operation of guided contact relays associated with the emergency circuit		New requirement; see note 16	Type 3 action	

4.8 Shaft sinking protection

Type of protection	Article [S-2.1, r. 19.1]	Proposed inspection frequency	Control PES	Monitoring PES
Crosshead that follows the bucket	320	Weekly	Type 1 action	X
Checking of the safety arm of the sinking crosshead	320	Weekly	Type 1 action	X
Overspeed in shaft, outside the upper and lower limits of travel	242, 232 4)	Weekly		X
Lower limit of travel (Max. 2 drum revolutions)	230, 233 2)	Weekly		X
Speed below the lower chair level (lower stops)	234	Weekly		X

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APPENDIX A: BLOCK DIAGRAM OF PES-CONTROLLED MINE HOIST

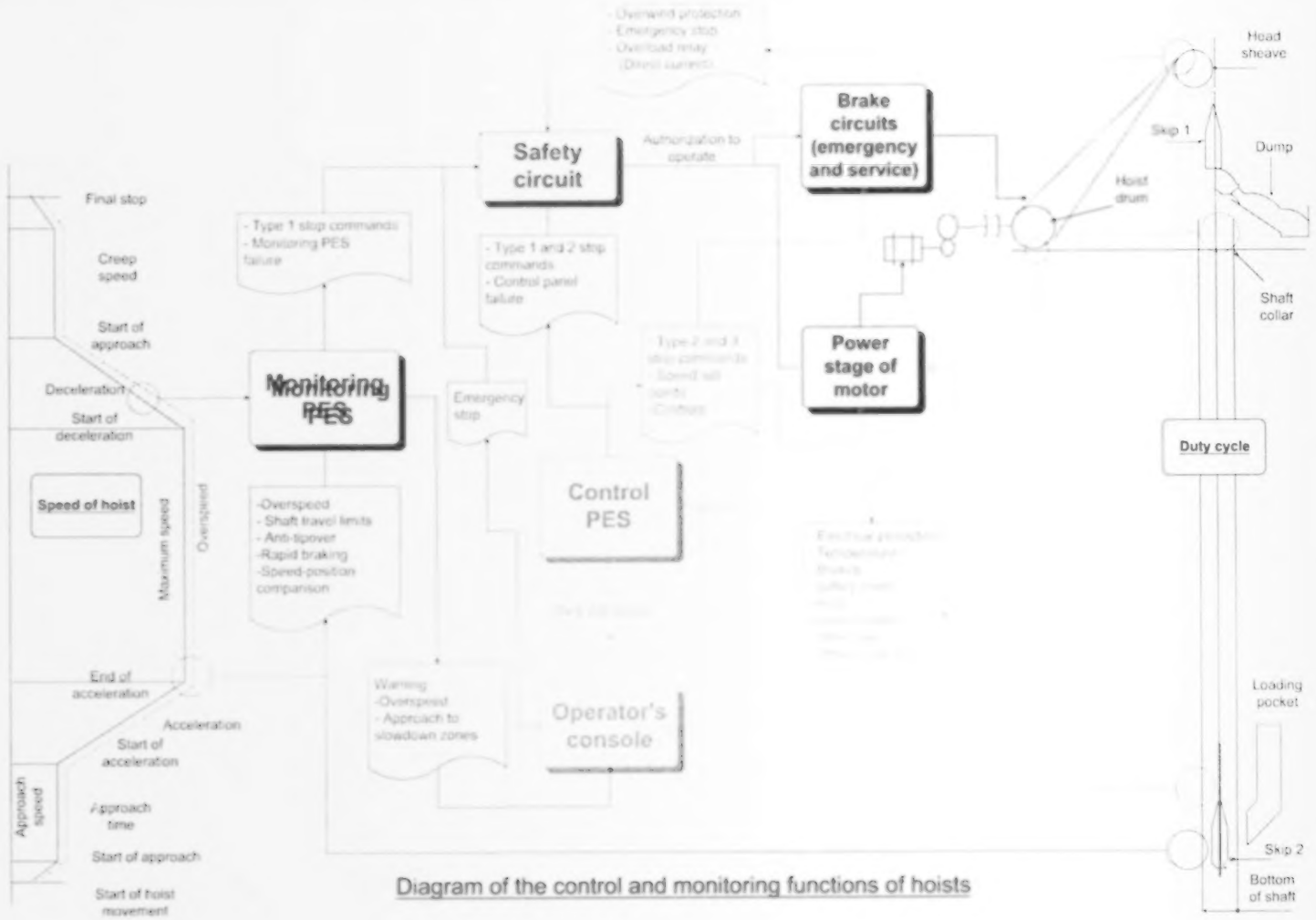

Diagram of the control and monitoring functions of hoists